UNCLASSIFIED

HW-51277

Radioactive Waste
(TID-4500, 13th Ed.)

CHANGES IN THE HANFORD WATER TABLE, 1944-1957

By

W. H. Bierschenk

Chemical Effluents Technology
Chemical Research and Development Operation

and

M. W. McConiga

Regional Monitoring
Radiation Protection Operation

July 9, 1957

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

Work performed under Contract No. W-31-109-Eng-52 between the Atomic Energy Commission and General Electric Company

Printed by/for the U. S. Atomic Energy Commission

Printed in USA. Price 75 cents. Available from the

Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C.

UNCLASSIFIED

Radioactive Waste
(TID-4500, 13th Ed.)

INTERNAL DISTRIBUTION

Copy Number	
1	B. V. Andersen
2	C. R. Anderson
3	F. W. Albaugh
4	G. E. Backman
5	W. H. Bierschenk
6	D. J. Brown
7	R. E. Brown
8	L. P. Bupp
9	R. E. Burns
10	H. V. Clukey
11	V. R. Cooper
12	E. E. Doud
13	R. L. Dickeman
14	J. B. Fecht
15	K. M. Harmon
16	J. W. Healy
17	K. R. Heid
18	O. F. Hill
19	J. F. Honstead
20	E. R. Irish
21	P. C. Jerman
22	A. R. Keene
23	C. E. Linderoth
24	M. W. McConiga
25	D. W. Pearce
26	J. R. Raymond
27	W. H. Reas
28	C. A. Rohrmann
29	P. P. Rowe
30	L. C. Schwendiman - W. A. Haney
31	H. P. Shaw - C. E. Kent
32	R. H. Silletto
33	R. E. Smith
34	H. F. Soule
35	R. E. Tomlinson - W. G. Browne
36	V. W. Wood
37	300 Files
38	Record Center
39 - 50	Extra

EXTERNAL DISTRIBUTION

Copy Number	
51 - 52	Aberdeen Proving Ground
53	Alco Products, Inc.
54 - 63	Argonne National Laboratory
64	Armed Forces Special Weapon Project, Washington
65 - 69	Armed Services Technical Information Agency, Dayton
70	Atlantic Fleet
71	Atomic Bomb Casualty Commission
72	Atomic Energy Commission, Patent Branch
73 - 75	Atomic Energy Commission, Technical Library
76 - 77	Atomics International
78 - 79	Battelle Memorial Institute
80 - 81	Bettis Plant
82 - 85	Brookhaven National Laboratory
86	Bureau of Medicine and Surgery
87	Bureau of Ships (Code 590)
88	Chicago Patent Group
89	Combustion Engineering, Inc.
90 - 91	Consolidated Vultee Aircraft Corporation
92	Convair-General Dynamics
93	Defence-Research Member
94	Department of Navy (Code 422)
95 - 96	Department of the Army, G-2
97	Division of Raw Materials, Denver
98	Dow Chemical Company, Pittsburg
99	Dow Chemical Company (Rocky Flats)
100 - 102	Du Pont de Nemours and Company, Aiken
103	Du Pont de Nemours and Company, Wilmington
104	Frankford Arsenal
105 - 106	General Electric Company (ANPP)
107	Goodyear Atomic Corporation
108	Grand Junction Operations Office
109	Hawaii Marine Laboratory
110 - 111	Iowa State College
112 - 113	Kirtland Air Force Base
114	Knolls Atomic Power Laboratory
115 - 116	Lockheed Aircraft Corporation (Bauer)
117 - 119	Los Alamos Scientific Laboratory
120	Mallinckrodt Chemical Works
121	Massachusetts Institute of Technology (Dr. Hardy)
122	Mound Laboratory
123	National Advisory Committee for Aeronautics, Cleveland

EXTERNAL DISTRIBUTION (Contd.)

Copy Number	
124 - 125	National Bureau of Standards, Atomic Energy Project
126	National Lead Company, Inc., Winchester
127	National Lead Company of Ohio
128 - 130	Naval Research Laboratory
131	New Brunswick Area Office
132 - 133	New York Operations Office
134	Nuclear Development Corporation of America
135	Nuclear Metals, Inc.
136	Oak Ridge Institute of Nuclear Studies
137 - 141	Oak Ridge National Laboratory
142 - 146	Office of Naval Research
147	Office of Surgeon General AFCSG-15
148 - 151	Phillips Petroleum Company
152 - 153	Public Health Service
154	Radioisotopes Laboratory
155	Sandia Corporation
156	Sylvania Electric Products, Inc.
157	Technical Operations, Incorporated
158 - 160	The Surgeon General
161	Union Carbide Nuclear Company (C-31 Plant)
162 - 163	Union Carbide Nuclear Company (K-25 Plant)
164 - 165	United Aircraft Corporation
166	U. S. Geological Survey, Denver
167	U. S. Geological Survey (Dr. Nolan)
168	U. S. Geological Survey, Naval Gun Factory
169	U. S. Geological Survey, Washington
170	U. S. Naval Postgraduate School
171 - 172	U. S. Naval Radiological Defense Laboratory
173	UCLA Medical Research Laboratory
174 - 175	University of California Radiation Laboratory, Berkeley
176 - 177	University of California Radiation Laboratory, Livermore
178	University of Rochester, Atomic Energy Project
179	Vitro Engineering Division
180	Walter Reed Army Medical Center
181	Watertown Arsenal
182	Weil, Dr. George L.
183	Westinghouse Electric Corporation
184 - 483	Technical Information Service Extension, Oak Ridge
484 - 558	Office of Technical Services, Washington

TABLE OF CONTENTS

CHANGES IN THE HANFORD WATER TABLE, 1944-1957

INTRODUCTION

Within nearly all the Hanford area the earth materials are sufficiently permeable that their contained water is essentially unconfined and drains down to a base level adjusted to that of the Columbia River. Thus, the zone naturally saturated with water is roughly 300 to 400 feet beneath the highest terrace in the north-central part of the area south of Gable Mountain. This zone is largely in the unconsolidated Ringold formation and to a lesser extent in the glacio-fluviatile deposits.[1] Subsequent to plant startup, appreciable changes have been made in the regional body of unconfined ground water by the infiltration of effluents released to ground during the 13 years of plant operation. The total volume of all liquids disposed to ground from various chemical processing plants during the period January 1944 through June 1957 amounts to more than 29 billion gallons, including over 2.8 billion gallons of low-level radioactive wastes.

With the addition of such large volumes of liquids to the ground-water reservoirs underlying the site, prediction of the behavior of the ground water becomes difficult inasmuch as increased hydraulic gradients and altered rates and directions of ground-water movement are imposed. Thus it is desirable to present basic hydrologic data which has been gathered since 1948 and which depict the changes in the water table. These changes are evident from a series of maps which show the shape and position of the water table by contour lines at successive stages of Hanford operations.

This report is based partially on a report by McConiga on changes in the Hanford water table from 1944 through 1955.[2]

SUMMARY

Maps showing generalized contours on the water table at Hanford indicate that throughout most of the area the general movement of ground water under natural conditions is from areas of recharge in the Rattlesnake

Hills northeastward and eastward to the Columbia River.

Open waste disposal swamps at the chemical processing plant areas have received approximately 26.6 billion gallons of process water since startup through June 1957, and covered disposal cribs and trenches have received approximately 2.8 billion gallons of low-level radioactive wastes.

With artificial recharge of waters from chemical processing plants to underlying aquifers, the water table has undergone significant changes. Of major importance is the formation of two separate and distinct ground-water mounds which have raised the water table considerably, increasing and locally reversing the natural hydraulic gradients. Through the years, the eastern mound has risen a known maximum of about 25 feet and the western mound a known maximum of about 90 feet. The size and shape of these mounds have fluctuated depending upon the locations of disposal sites and the rates and total volumes of waste water disposed. The relative size and shape of the mounds reflect differences in the hydraulic characteristics of the receiving aquifers.

METHODS OF INVESTIGATION

The ground-water contour maps are based on the measured altitude of the water surface in a pattern of wells, the contour lines representing lines of equal altitude on the water table expressed in feet above mean sea level. These maps show the hydraulic gradient and the direction in which the ground water is moving, and hence they show the source and destination of the ground water. The direction of movement generally is at right angles to the contour lines in the direction of the downward slope.

Irregularities in the shape and slope of the water table, shown on following figures, are caused largely (1) by recharge of the ground-water reservoir by plant effluents, (2) by local differences in the thickness and permeability of the unconsolidated deposits, and (3) by river-level fluctuations.

The area encompassed by Hanford Works is liberally dotted with a variety of wells that have been constructed over a period of time from pre-plant days to the present. The older wells were farm wells for which accurate drilling data are lacking. Many of the more recent wells were constructed to provide sanitary water for outlying Army installations, to permit monitoring the ground water and subsurface formations in the vicinity of waste disposal facilities, or to provide data for the detailed geological mapping of the region. Some of the wells for which records are available have been destroyed during construction of new plants or for safety reasons.(3) At present, 117 wells are measured regularly to give water-table elevations. The greatest number of these wells are adjacent to ground-water mounds, permitting at these locations rather accurate contouring of the water table. The few data available for those areas lying north of Gable Mountain and immediately northeast of Rattlesnake Hills require liberal interpretation and generalization, and there may be substantial deviation, at least in detail, from the shape and position of the contours as shown (see following paragraphs).

Ground-Water Contours, January 1944

The Hanford region lies in the rain shadow of the Cascade Mountains. It has an average annual rainfall of about seven inches, little or none of which penetrates to the water table beneath plant areas where the depth to water is as much as 350 feet. Thus, as indicated in Figure 1, the source of ground water is precipitation upon Rattlesnake Hills to the southwest and (not shown) upon Yakima Range to the west. The water percolates underground near the base of the highlands and moves down gradient in a general northeastward and eastward direction toward the Columbia River. Adjacent to, and from one to three miles distant from the river, the regional body of ground water enters a zone in which both direction and rate of movement varies widely, depending on fluctuations of river stage. Discharge of ground water from the area is thus by percolation into the river so long as the river is not at a high stage.

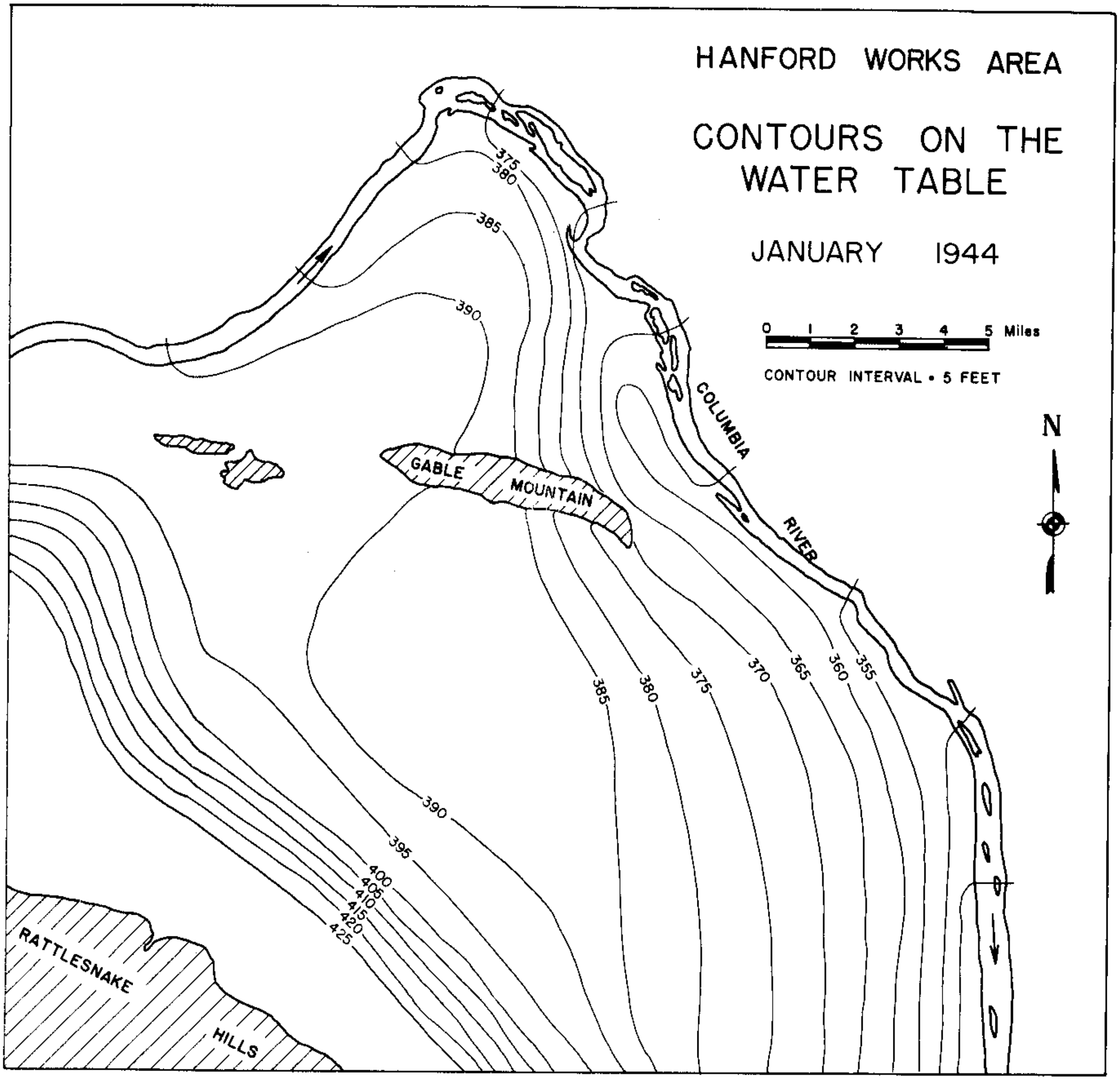
HANFORD WORKS AREA
CONTOURS ON THE WATER TABLE
JANUARY 1944
0 1 2 3 4 5 Miles
CONTOUR INTERVAL • 5 FEET
N
COLUMBIA RIVER
GABLE MOUNTAIN
RATTLESNAKE HILLS
375
380
385
390
395
400
405
410
415
420
425
370
365
360
355

FIGURE 1

Figure 1 shows the contours on the water table as they probably occurred prior to plant operation. This contour map is based on scanty data, but nevertheless the generalizations are believed reasonable.

Ground-Water Contours, March 1951

Figure 2 shows the shape and position of the water table after about seven years of plant operation. The two principal features shown are an eastern and a western ground-water mound which had been built up as the result of disposal and subsequent infiltration of non-radioactive cooling waters from chemical processing facilities located in the vicinity. The three wells shown on Figure 2 (Wells A, B, and C), and on subsequent figures are located near the several open disposal swamps, and water-level measurements made in them best represent the known apex altitudes of the mounds.

The formation of the ground-water mounds above the level of the natural water table significantly altered the directions and rates of ground-water movement. Whereas the natural gradient beneath the western and eastern plant sites was about 5 feet per mile northeasterly and easterly, respectively, the mounds both locally reverse and increase the gradient. Thus, the ground water flowed outward radially from the mounds, and, under the influence of a 20-foot per mile average gradient in the west and a 10-foot per mile average gradient in the east, at velocities several times greater than under natural conditions previously.

The two mounds were formed by approximately equal volumes of disposed water, about 5.5 billion gallons to both the eastern and western areas. Consequently, water levels beneath the eastern area rose an estimated maximum of approximately 15 feet, or from an elevation of less than 390 feet above mean sea level to over 405 feet; and levels beneath the western area rose a maximum of about 55 feet, or from an elevation of about 395 feet to about 450 feet. The differences in the size and shape of the mounds are attributed chiefly to differences in permeabilities of the

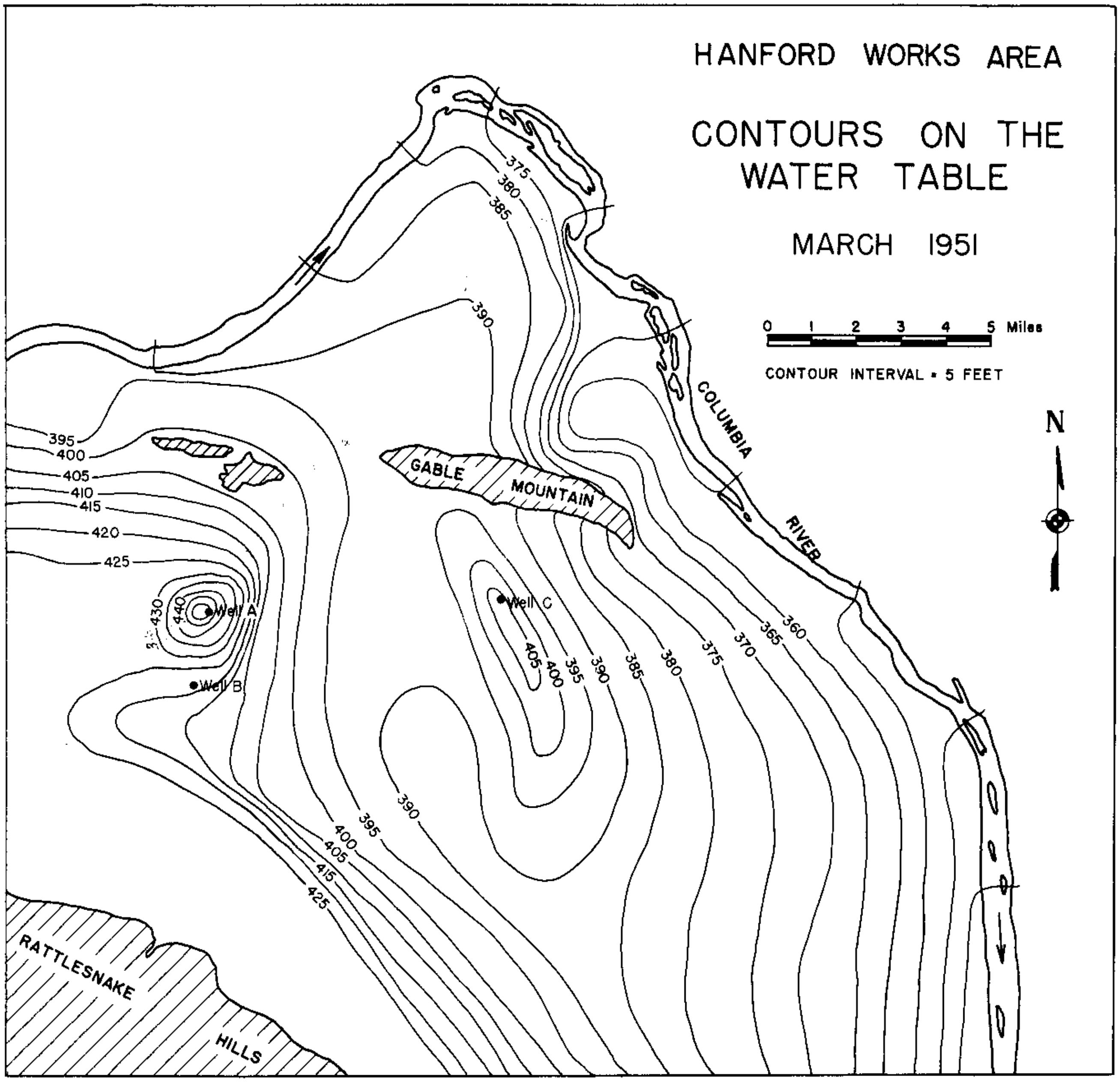
HANFORD WORKS AREA
CONTOURS ON THE WATER TABLE
MARCH 1951
0 1 2 3 4 5 Miles
CONTOUR INTERVAL = 5 FEET
N
COLUMBIA RIVER
GABLE MOUNTAIN
RATTLESNAKE HILLS
Well A
Well B
Well C
360
365
370
375
380
385
390
395
400
405
410
415
420
425
430
440

FIGURE 2

underlying sediments. From the western edge of the figure eastward about seven miles, the underlying aquifers are composed of fine-grained sands, silts, and clays of the Ringold and Touchet formations.[1] These sediments have been partially stripped away beneath the eastern area by glacio-fluviatile erosion and replaced by more permeable coarse-grained sands and gravels.

The elongation of the eastern ground-water mound is due to the upwarping of a two-mile wide belt of Ringold clays which rises above the water table near well C with a general northwesterly strike. Consequently, the ground water moves much more freely through the more permeable sands to the west and thus preferentially in northwestward and southeastward directions.

Ground-Water Contours, May 1953

Changes in the operation of processing facilities early in 1952 resulted in large reductions of flow to the eastern disposal swamp and the establishment of new disposal swamps in the two-mile region between wells A and B in the western area.

Figure 3 shows contours as of May 1953. The western mound as shown is the result of disposing of about 2.5 million gallons per day (mgd) of cooling water to the northern swamp in this area, and roughly 6-7 mgd to the southern swamp. Thus the water level in well A at the north rose to an altitude of over 460 feet, or an increase of 10 feet since March 1951, and to the south in well B the level rose to about 455 feet, an increase of over 30 feet.

The eastern ground-water mound as shown had subsided some 5 feet since March 1951 as the result of the swamp near well C receiving only 0.1 mgd as compared to the former rate of about 2 mgd.

The easternmost contours near the Columbia River show that during periods of high flow when the river runs bank-full, some of the water seeps

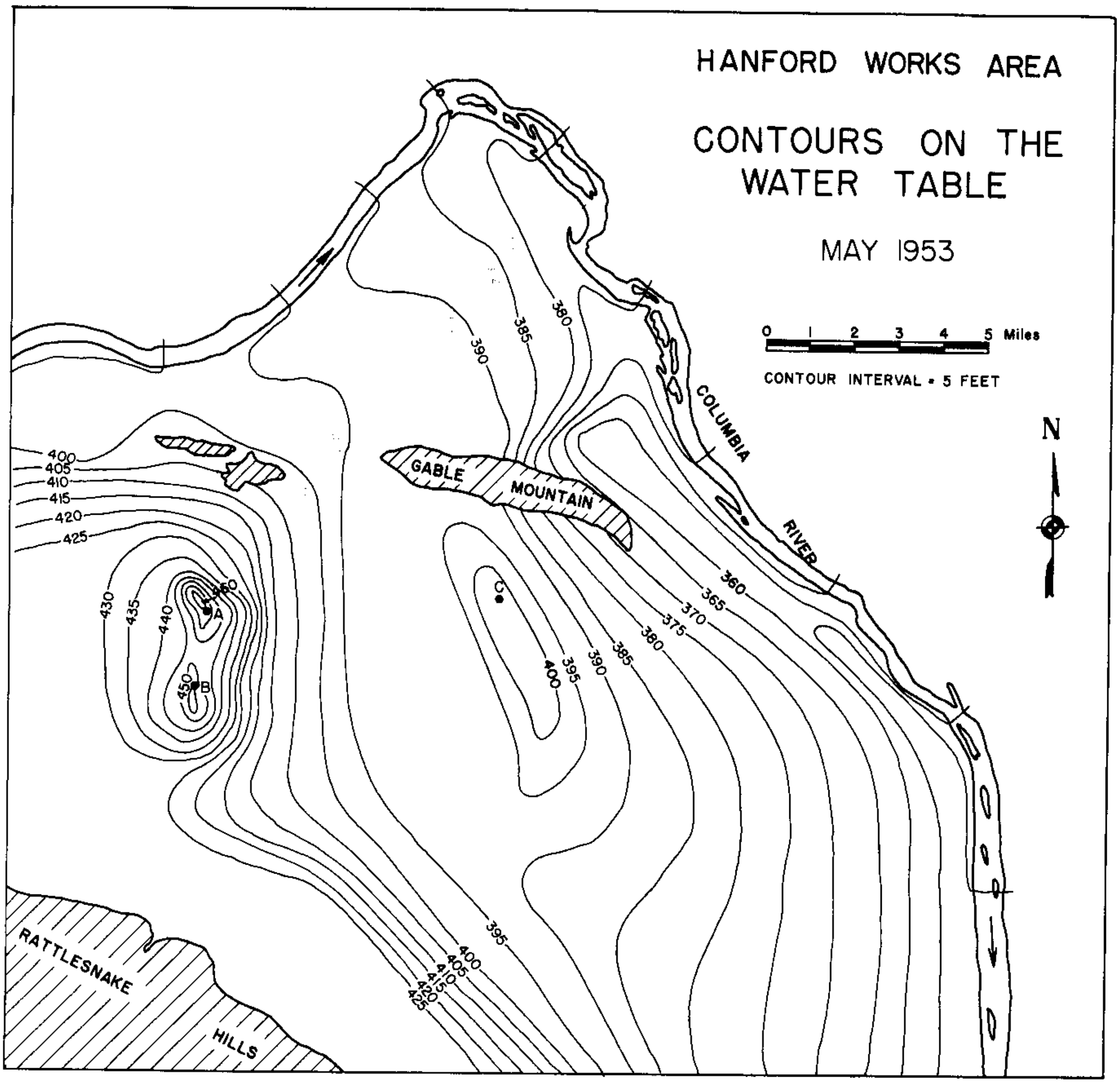
HANFORD WORKS AREA
CONTOURS ON THE WATER TABLE
MAY 1953
0 1 2 3 4 5 Miles
CONTOUR INTERVAL = 5 FEET
N
COLUMBIA RIVER
GABLE MOUNTAIN
RATTLESNAKE HILLS
A
B
C
400
405
410
415
420
425
430
435
440
450
460
395
390
385
380
375
370
365
360

FIGURE 3

downward to the ground-water reservoir. (The river generally crests in the month of June, and it has a low water period which extends from September to April.) Subsequently, when flood flow diminishes and the river resumes its normal stage, the ground water temporarily stored in adjacent aquifers is discharged slowly until ground water levels again approach the normal stage.

Ground-Water Contours, October 1955

Figure 4 shows ground-water contours as of October 1955. The several components of the western ground-water mound as seen in Figure 3 had joined to form a single peak beneath the northern swamp near well A. At this time roughly 3.5 mgd of cooling water were being discharged to the swamp at A and about 5-6 mgd to swamps at B. The western mound had risen an additional 25 feet in the north since May 1953 and about 20 feet in the south; the peak standing at an altitude of over 485 feet, more than 90 feet higher than the inferred pre-plant level.

Only a remnant of the eastern ground-water mound remained at this time as the water level in well C fell almost 10 feet from its peak elevation of about 405 feet (Figure 2). Shortly hereafter, water samples from wells to the southeast showed trace concentrations of radioactive materials apparently moving with velocities in the order of hundreds of feet per day. Such movement was probably initiated by the subsidence of this eastern mound which presumably had partially blocked the flow to the southeast. These high velocities were later confirmed by a large-scale fluorescein tracer test in the area. This test showed detectable amounts of fluorescein in observation wells 8,800 feet south-southwest and 8,500 feet southeast of a treated well, representing average linear velocities of 350 and 770 feet per day, respectively.

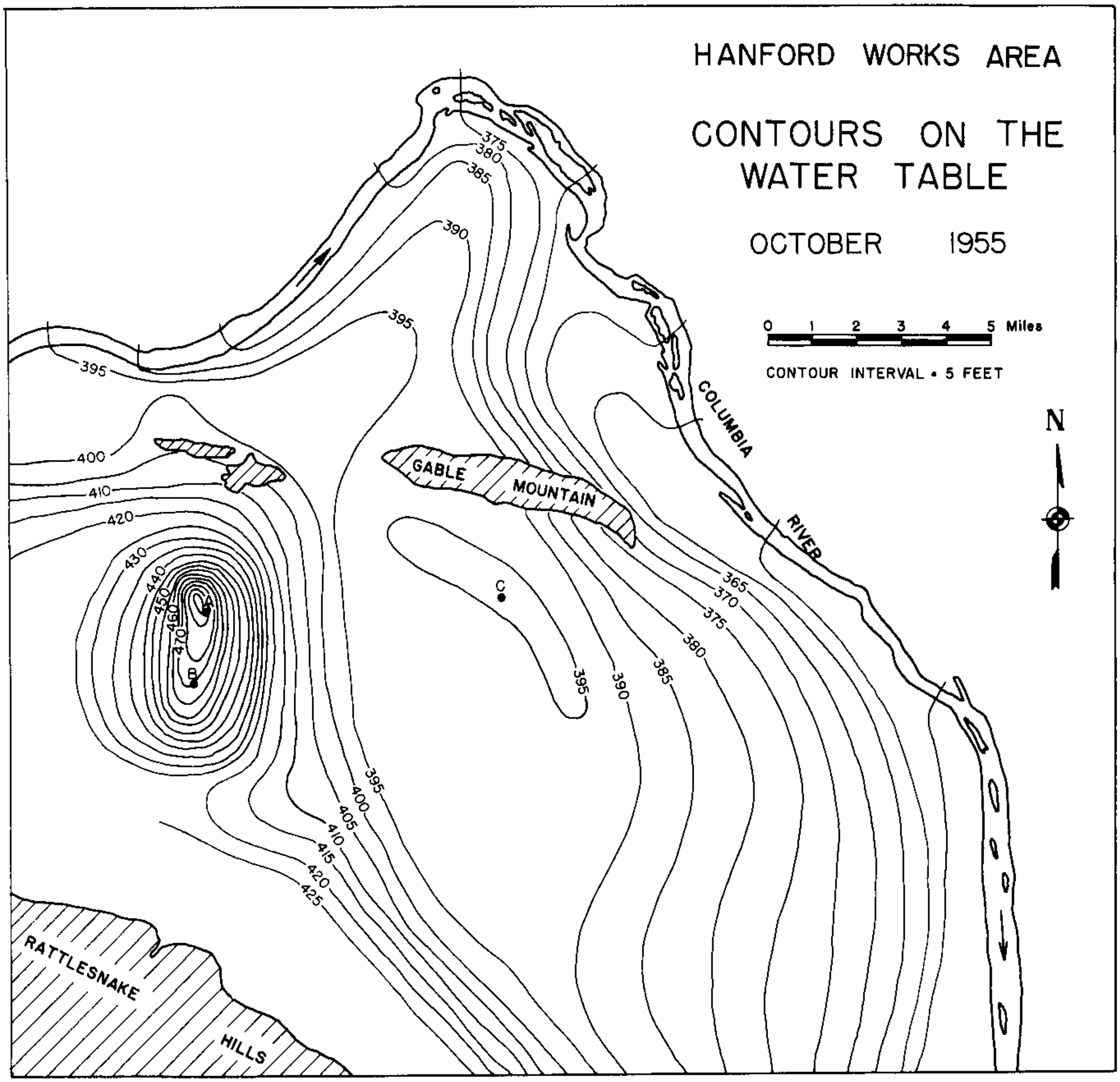
HANFORD WORKS AREA
CONTOURS ON THE WATER TABLE
OCTOBER 1955
0 1 2 3 4 5 Miles
CONTOUR INTERVAL • 5 FEET
N
COLUMBIA
RIVER
GABLE
MOUNTAIN
RATTLESNAKE
HILLS
A
B
C
365
370
375
380
385
390
395
400
405
410
415
420
425
430
440
450
460
470

FIGURE 4

Ground-Water Contours, October 1956

Early in 1956 the swamp site near well C started to receive additional cooling water. The rate of discharge reached a level more than three times higher than that originally disposed to the facility, or averaging approximately 6.5 mgd. At about the same time the rate of discharge of cooling water to the swamp near well A to the west was decreased from 3.5 to 0.1 mgd; roughly 5-6 million gallons per day continued to flow to the swamps near well B.

The effect of these operations is shown in Figure 5; the contours were drawn one year after those of Figure 4. The eastern ground-water mound built up to a maximum known elevation of over 405 feet, an increase of more than 10 feet since October 1955. The addition of several new wells in the area indicated for the first time the presence of a westward-trending projection at the southern end of the mound. The eastward shifting of the 395-foot contour that had been present between the two mounds shows that water levels between the mounds had risen at least as much as 5 feet during the year.

The western ground-water mound continued its uniform lateral spreading in all directions, but more significantly, the peak of the mound shifted from near well A southward to near well B. A well-defined north and northeastward gradient of about 25 feet per mile thus replaced a south and southeastward gradient as the water level in well A fell roughly 20 feet in one year and levels in well B rose about 5 feet to an altitude just over 475 feet.

Ground-Water Contours, June 1957

Figure 6 shows the ground-water contours as of June 1957. Changes in the position and details of the contours are principally the result of incorporating data from 14 additional wells in the well pattern; thus a total of 117 wells provided control for the contours as shown.

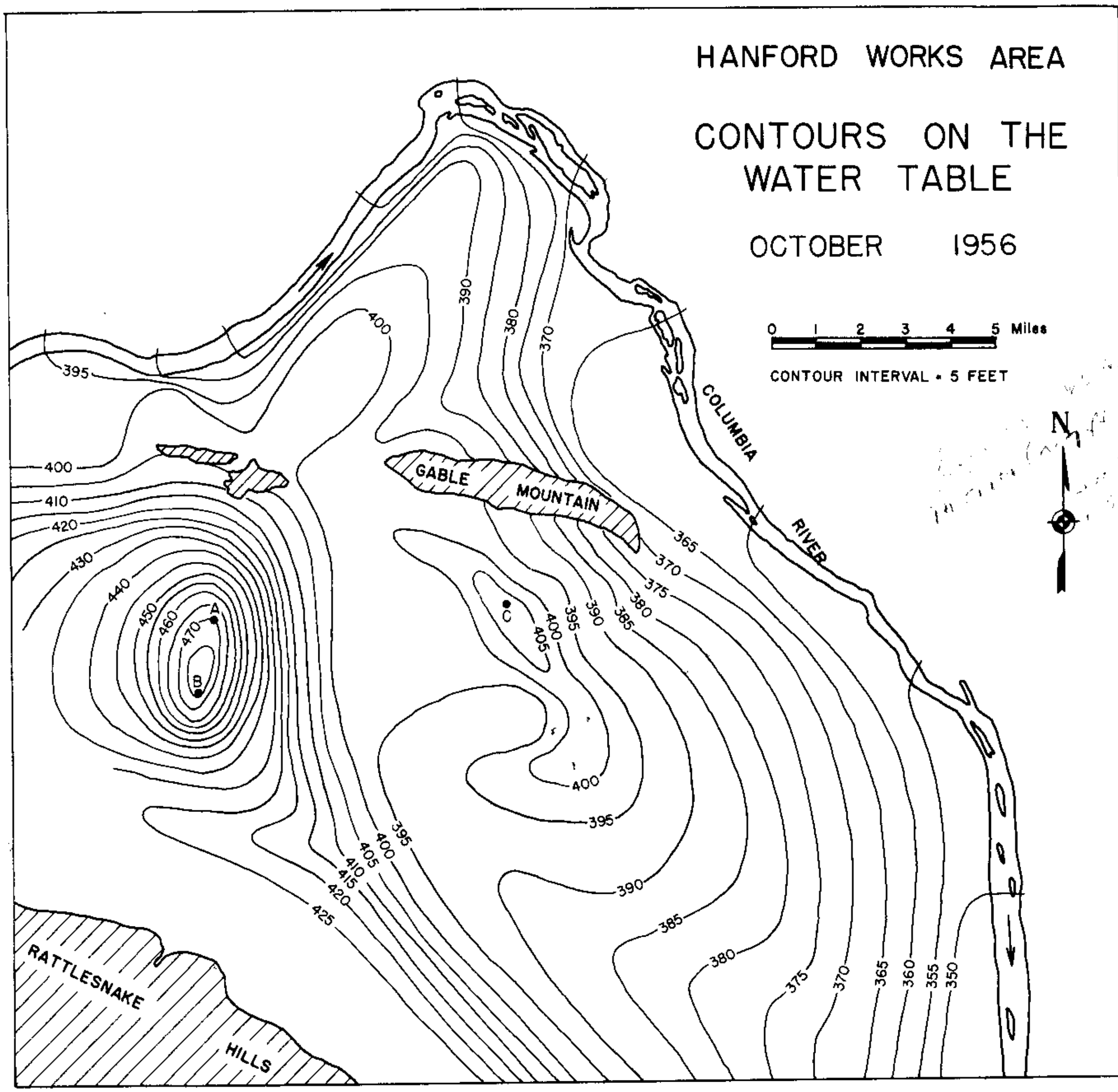

FIGURE 5

AEC-GE RICHLAND, WASH.

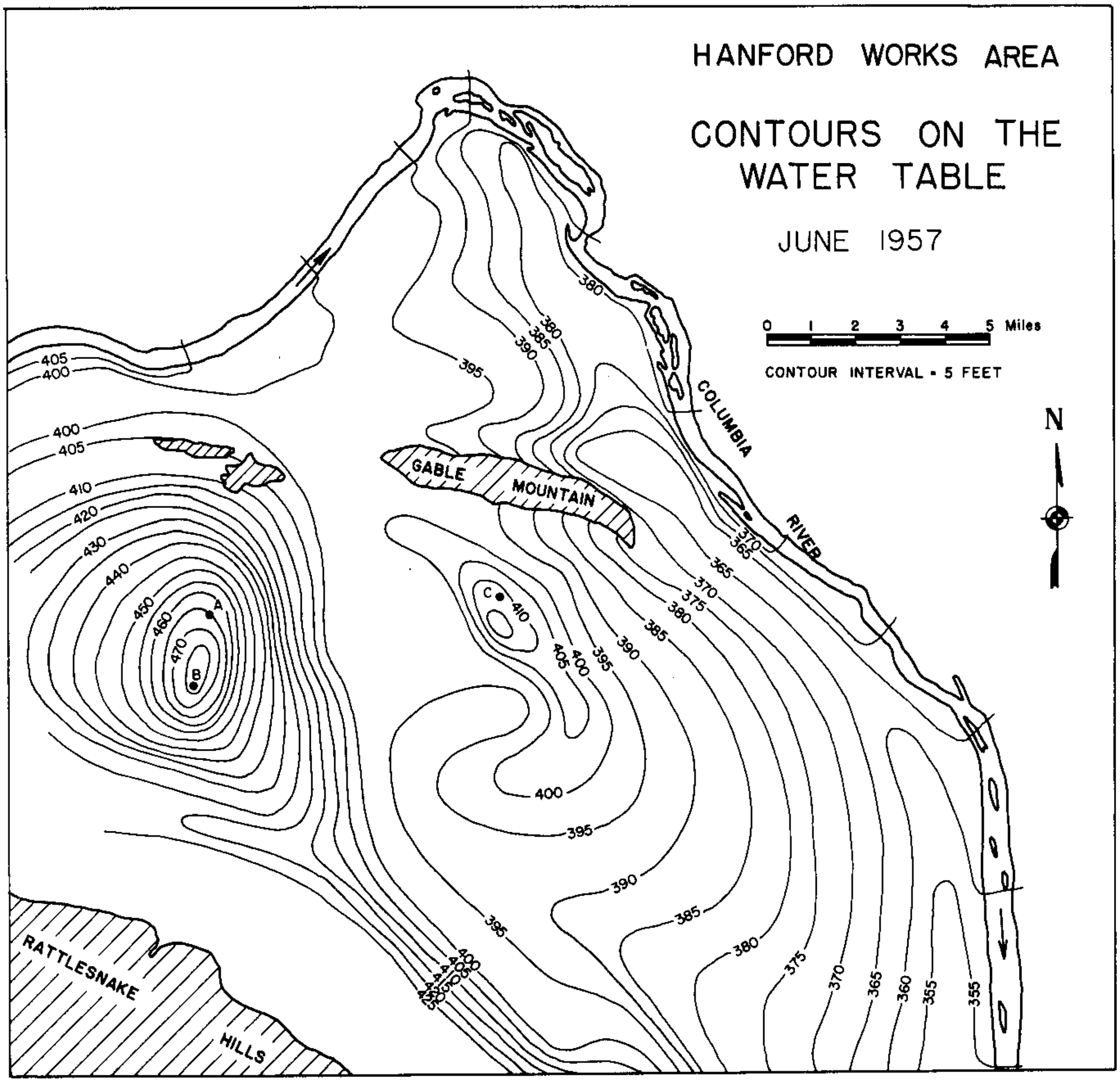
HANFORD WORKS AREA
CONTOURS ON THE WATER TABLE
JUNE 1957
0 1 2 3 4 5 Miles
CONTOUR INTERVAL = 5 FEET
N
COLUMBIA
RIVER
GABLE
MOUNTAIN
RATTLESNAKE
HILLS
A
B
C
405
400
410
420
430
440
450
460
470
395
390
385
380
375
370
365
360
355

FIGURE 6

The contours north of Gable Mountain and along the eastern edge of the project are obviously influenced by peak river stage, but the general eastward shifting of the contours at the north resulted primarily from data from six new wells. The flattening of the contours at the southern end of the western ground-water mound is probably caused by the presence of a buried basalt ridge. This ridge roughly parallels Rattlesnake Hills at a distance of about three miles and locally rises above the water table.

Less than a mile south of well C, a new well has located more accurately the known apex of the eastern ground-water mound. Thus, whereas the water level in well C rose about 5 feet since October 1956 (Figure 5) and stands approximately 5 feet higher than the previously described peak altitude of the eastern mound (Figure 2) and some 20 feet higher than the pre-plant water table (Figure 1), an apex altitude of 418 feet currently is located to the south of well C.

Further adjustments of the details in the shape and position of the ground-water contours may be expected as the well-drilling program progresses throughout the area and additional water-level data are made available.

CONCLUSIONS

The total volume and rate of flow of liquid effluents recharged to underlying aquifers, as well as the hydraulic characteristics of the aquifers, govern the size, shape, and orientation of consequent ground-water mounds. The two ground-water mounds at Hanford have increased and locally reversed natural hydraulic gradients, and thus have accelerated the movement of ground waters in certain areas. The locations of disposal sites are therefore so chosen that the acceptable concentration of short-lived radioisotopes permitted in the underlying ground waters need not be restricted by these increased rates of ground-water movement. Future large-scale disposal of cooling water will be regulated to permit optimum utilization of existing and proposed waste disposal sites.[4]

Experience at Hanford indicates that nuclear chemical processing plants using ground disposal of low-level radioactive wastes should consider the regulation of cooling water disposal and the formation of large ground water mounds. Factors which may influence the mode of disposal of large cooling water volumes include:

1. The potential for low-level contamination of the cooling water resulting from minor leaks in the plant or occasional operator error makes ponding an attractive method as opposed to direct discharge to a stream. The expense of automatic monitoring and diversion of large streams may be thus minimized.

2. Ponding such cooling water will probably result in significant alteration of the local hydrologic pattern with the consequent influence on the capacity of nearby ground disposal facilities for receiving low-level radioactive wastes. This influence may be minimized by the judicious location of facilities.

REFERENCES

1. Bierschenk, W. H., Hydraulic Characteristics of Hanford Aquifers, HW-48916, March 3, 1957, (UNCLASSIFIED).

2. McConiga, M. W., Changes in the Hanford Ground-Water Table, 1944-1955, HW-40469, December 1, 1955, (CONFIDENTIAL).

3. Honstead, J. F., Brown, R. E., and Brown, D. J., Hanford Wells, HW-44355, July 19, 1956, (UNCLASSIFIED).

4. Bierschenk, W. H., The Effect of Ground-Water Mounds on the Purex Operation, HW-49728, April 18, 1957, (UNCLASSIFIED).